10.2478/v10246-012-0018-1

ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN–POLONIA

VOL. LXVIII SECTIO AAA 2013

About a new suggested interpretation of special theory of relativity within a three-dimensional Euclid space

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ABSTRACT

An interpretation of special theory of relativity is proposed, in which the fundamental arena of physical processes is an Euclid three-dimensional space where time exists only as a numerical order of material changes and the duration of material changes is a proper, physical scaling function of the numerical order. This model introduces interesting perspectives in the study of several phenomena inside special relativity, such as aberration of light, Doppler effect, Jupiter's satellites occultation and radar ranging of the planets.

1. INTRODUCTION

Special theory of relativity is, together with general relativity and quantum mechanics, one of the three fundamental theories of modern physics which have radically revolutionised our view of the world. In essence, this theory, as was developed by Einstein in 1905, ironed-out the inconsistencies between Newtonian mechanics and Maxwellian electrodynamics concerning absolute motion and the laws of physics. In order to explain the results of the famous Michelson-Morley experiment Einstein put forward the following two postulates:

1) The laws of physics are the same for all inertial frames of reference in uniform relative motion.

2) The speed of light in free space is the same for all inertial observers.

The first postulate, also known as the principle of Relativity, dispels the notion that there is such a thing as a preferred or absolute reference system. According to the first postulate, the laws of physics must have the same form in equivalent reference systems. Inertial reference systems have the same status of motion in that Newton's first law holds good in them. If the first postulate were true and Maxwell's theory were a fundamental theory of nature, then the second postulate follows immediately since Maxwell's theory predicts explicitly that the speed of light has a definite numerical value. The constancy of the speed of light predicted here lead us via Einstein's great insight to rethink our view of space and time. Time for different frames of reference runs at different rates and lengths are not absolute but depend on the observers' state of motion.

Then, three years after Einstein's work, Minkowski introduced the idea of a fundamental four-dimensional (4D) spacetime continuum as a conceptual framework for Einstein's theory of special relativity. Yet despite the indelible impression Minkowski's insight has left on our thinking, relativity is not fundamentally about spacetime. It is foremost concerned with how different observers view the world around them, and how their views relate to each other. The spacetime perspective is compelling precisely because it efficiently accounts for all these possible viewpoints.

On the other hand, 4D spacetime is not the only framework for understanding observers. For example, Selleri proposed general transformations of space and time between inertial reference frames that seem to indicate clearly that in special relativity time must be separated from space [1, 2, 3]. Given the inertial frames S_0 and S' endowed with Cartesian coordinates x_0, y_0, z_0 and x', y', z' respectively (where the origin of S', observed from S_0, is seen to move with velocity $v<c$ parallel to the $+x_0$ axis), by starting from the following two empirically based assumptions:

1. the two-way velocity of light is the same in all directions and in all inertial systems;

2. clock retardation takes place with the usual velocity dependent factor when clocks move with respect to S_0,

Selleri found the following transformations for the space and time variables from S_0 to S' (called also equivalent transformations):

$$\begin{cases} x' = \dfrac{x_0 - vt_0}{\sqrt{1-\beta^2}} \\ y' = y_0 \\ z' = z_0 \\ t' = \sqrt{1-\beta^2}\, t_0 + e_1 (x_0 - vt_0) \end{cases} \tag{1}$$

where $\beta = \frac{v}{c}$. These transformations contain a free parameter, e_1, the coefficient of *x'* in the transformations of time which can be fixed by choosing a peculiar clock synchronization method in S'. The special theory of relativity (and thus the standard Lorentz transformations) is obtained for

$$e_1 = -\frac{\beta}{c\sqrt{1-\beta^2}} \tag{2}$$

For all the values of e_1 except (2), the system S_0 turns out to be a privileged reference frame. As analyzed by Selleri, different values of e_1 determine different theories of space and time which are empirically equivalent to a large extent (for example, Michelson-type experiments [4], the twin paradox experiment [5], radar ranging of planets and occultation of Jupiter satellites [6], Doppler effect and aberration [7], Fizeau experiment [8] are insensitive to the choice of e_1). But, as it was shown by Selleri, there are some particular phenomena (the accelerating spaceships, the rotating disk and the question of superluminal signals regarding the group velocity of electromagnetic radiation) that modify the situation to the point that the condition $e_1 = 0$ becomes necessary. The adoption of $e_1 = 0$ makes equations (1) become the "inertial transformations", in which the transformation of the speed of clock does not contain the space variable:

$$\begin{cases} x' = \dfrac{x_0 - vt_0}{\sqrt{1-\beta^2}} \\ y' = y_0 \\ z' = z_0 \\ t' = \sqrt{1-\beta^2}\, t_0 \end{cases} \tag{3}$$

Selleri's theory of inertial transformations (3) determines an arena of Special Relativity, in which the temporal coordinate must be clearly considered as a different entity with respect to the spatial coordinates just because the transformation of clocks' run between the two inertial systems does not depend on the spatial coordinates. Moreover, in the theory of the inertial transformations (3), the inertial reference frame S_0 is not only privileged but also physically active in the sense that clocks run slower when they move with respect to S_0 and light propagates in the simplest way only in S_0. It is the motion relative to S_0 that influences the clocks' running. According to the inertial transformations (3), the origin of S_0, observed from *S*, is seen to move with velocity $-\beta c / \left(1-\frac{v^2}{c^2}\right)$. The latter velocity can be larger than c , but cannot be superluminal. In fact, if a particle moves with velocities v_p and u_p, relative to S_0 and *S'* respectively, equations (3) lead to the following transformations of velocities:

$$\begin{cases} u_{px} = \dfrac{v_{px} - v}{1-\beta^2} \\ u_{py} = \dfrac{1}{\sqrt{1-\beta^2}}\, v_{py} \\ u_{pz} = \dfrac{1}{\sqrt{1-\beta^2}}\, v_{pz} \end{cases} \tag{4}$$

Setting $u_{px} = u_p \cos\vartheta$, $u_{py} = u_p \sin\vartheta$, $u_{pz} = 0$ (where ϑ is the angle, in S, between u_p and v_p), one easily obtains

$$v_p = \sqrt{\left(v + \left(1-\beta^2\right)u_p \cos\vartheta\right)^2 + \left(\left(1-\beta^2\right)u_p \sin\vartheta\right)^2}. \tag{5}$$

As a consequence of equation (5), in the approach of the inertial transformations the velocity of light is isotropic only in S_0. A luminous pulse travelling in the direction −*x*' with respect to the velocity of *S*' relative to S_0 has a velocity given by

$$c_1(\vartheta) = \frac{c}{1+\beta\cos\vartheta} \tag{6}$$

where $\vartheta = \pi$, namely

$$\tilde{c}(\pi) = \frac{c}{1-\beta} \tag{7}$$

which is certainly larger than $\beta c / \left(1-\frac{v^2}{c^2}\right)$, if $0 \le \beta < 1$. Thus, in Selleri's approach of the inertial transformations, the relative velocities, in any direction ϑ can grow without limit, but they always remain smaller than $c_1(\vartheta)$. The absolute velocities can never be larger than *c*.

In this paper, our aim is to make another step further beyond Selleri's results by proposing a new alternative interpretation of special relativity in which the fundamental arena of processes is a three-dimensional (3D) Euclid space and time has a secondary ontological status in the sense that represents only a mathematical coordinate which measures the numerical order of material changes. We can call this approach as the "3D interpretation" of special relativity. This paper is structured in the following manner. In chapter 2 we will analyse the fundamental features of this approach and we will show how this approach allows us to re-obtain the same formalism of Einstein (but inside a different physical picture). In chapters 3, 4, 5 and 6 we will analyse how this "3D interpretation" of special relativity allows us to re-read some significant phenomena of special relativity, such as aberration of light, Doppler effect, Jupiter's satellites occultation and radar ranging of the planets.

2. THE FUNDAMENTAL FEATURES OF THE "THREE-DIMENSIONAL" INTERPRETATION OF SPECIAL RELATIVITY

Einstein's formalism of special relativity based on the standard Lorentz transformations may be derived from a more fundamental 3D Euclidean space, with Galilean transformations for the three spatial dimensions and Selleri's transformation for the rate of clocks. Let a moving inertial system o' observed from rest system o move with respect to the inertial system o with constant velocity $v<c$ parallel to the X axis. The Galilean transformations between the spatial coordinates X, Y, Z of the inertial system o and the spatial coordinates X', Y', Z' of the inertial system o' are the following

$$X' = X - v \cdot \tau$$
$$Y' = Y$$
$$Z' = Z \tag{8}$$

where v is the velocity of the moving observer O' measured by the stationary observer O and τ is the proper time of the observer O (namely the speed of clock of the observer O). Equations (8) are valid for both observers O and O' of the inertial systems o and o'. The transformation of the rate of clocks, and thus between the proper time τ of the observer O and the proper time τ' of the observer O' is given by Selleri's formalism [1, 2, 3]:

$$\tau' = \sqrt{1 - \frac{v^2}{c^2}} \cdot \tau \tag{9}$$

Equation (9) shows clearly that the speed of the moving clock (namely the proper time of the moving observer) does not depend on the spatial coordinates but is linked only with the speed v of the inertial system O'. This indicates that relative velocity has origin in fundamental properties of space which are changed by the kinetic energy due to the velocity v of a given inertial system moving in space [9].

The formalisms (8) and (9) mean that time and space represent two separated entities, two different physical realities. Equations (8) and (9) determine an arena of Special Relativity in which the temporal coordinate must be clearly considered as a different entity with respect to the spatial coordinates just because the transformation of the speed of clocks between the two inertial systems does not depend on the spatial coordinates. According to equation (9) one can say that the three spatial coordinates of the two inertial systems turn out to have a primary ontological status, define an arena that must be considered more fundamental than the standard space-time coordinates interpreted in the sense of Einstein. On the basis of equations (8) and (9) we can conclude therefore that the real arena of special relativity is not a mixed 4D space-time but rather a 3D space where time does not represent a fourth coordinate of space but must be considered merely as a mathematical quantity measuring the numerical order of material changes. Clocks are measuring devices of the numerical order of material motion: each clock can be associated with a specific proper time. A clock as a measuring device of numerical order of material change in an experiment runs slower (generally, all material changes run slower) in a faster inertial system o than in an inertial system at rest o. Experiments with clocks in a fast airplane do confirm that these relative velocities are valid for both observers O and O'.

Each material motion determines a peculiar "scaling" factor of the proper time and of the spatial coordinates. Equation (9) can be scaled by any arbitrary number which replaces τ by a new proper time $\widetilde{\tau}$. Since by substituting this new proper time into equations (8) one obtains a different result for the transformation of the spatial coordinates, here our idea is to define the concept of physical duration of motion as a proper, "true", physical scale for the proper time τ , namely for the numerical order. We define the physical, measurable time – intended as duration of material change – just as this proper, true, physical scale for the numerical order. More precisely, we assume here that the duration of material motion measured by the stationary observer can be associated with a peculiar scaling physical factor of the numerical order of the form:

$$t = \alpha(v, X, \tau) \tag{10}$$

where the scaling factor α is a function also of the velocity of the moving frame with respect to the rest frame and of the position of the material object with respect to the rest frame.

The velocity of a material object can be considered as the physical entity which derives from the duration (namely from this true physical scale α of the numerical order) as well as from the position of the object. In other words, the motion of each material object and of each reference frame can be associated with the duration of material change defined as this peculiar physical scaling factor α of the numerical order as well as with the spatial coordinates. The notion of velocity derives just from the physical scale of the numerical order and from the spatial coordinates.

In particular, here we assume to make the following choice for the scaling function α :

$$t = \tau\left(1-\frac{v^2}{c^2}\right)+\frac{vX}{c^2} \tag{11}$$

The physical time *t*, defined by equation (11) represents the duration of material motion as measured by the stationary observer O in the rest inertial frame o. Equation (11) indicates that the physical time as a duration of material change emerges from a more fundamental numerical order. On the basis of equation (11), the numerical order may be considered as the internal structure of the physical, measurable time intended as duration.

The duration of material change, since it is a physical scale of the numerical order, follows a transformation law analogous to equation (9). In other words, the physical time *t'* – representing the duration of the material motion measured by the moving observer O' in the inertial frame o' – will be linked to *t* by a transformation law similar to equation (9). Thus, by substituting equation (9) into equation (11) one obtains the following transformation for the duration of material motion:

$$t'\frac{1}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}\left(1-\frac{v^2}{c^2}\right)+\frac{vX}{c^2}=t \tag{12}$$

namely

$$t'\sqrt{\left(1-\frac{v^2}{c^2}\right)}+\frac{vX}{c^2}=t \tag{13}$$

namely

$$t' = \frac{t - \frac{vX}{c^2}}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}} \tag{14}$$

which coincides with the standard Lorentz transformation for the time coordinate. We have thus shown that the Lorentz transformation for the time coordinate of standard Einsteinian special relativity emerges as a consequence of the more fundamental transformation for the numerical order of material changes and that the time coordinate of Einstein intended as duration of material change can be seen as a physical scaling factor of the numerical order of material change on the basis of equation (11). According to the authors, this is an important indication that the standard 4D space-time arena does not represent the fundamental arena of special relativity but rather emerges from a more fundamental 3D arena where time exists only as a numerical order of material changes (and the physical duration emerges as a physical scaling function of this numerical order).

Now, let us see how one can derive the standard Lorentz transformation for the first spatial coordinate by starting from the 3D arena described by equations (8) and (9) and the duration of material changes (11). In this regard, before all, we write the inverse of equation (11):

$$\tau = \frac{t - \frac{vX}{c^2}}{1 - \frac{v^2}{c^2}} \tag{15}$$

Now, the re-scaling of the numerical order determined by the material motion indirectly acts on the measurement of the position of the material object in the moving inertial frame. There is therefore a re-scaling of the position of the material object into consideration as a consequence of its motion as measured by the observer in motion. In particular, it seems permissible to assume that the effect of the duration of the motion of the material object is to originate the following scaling change of the first spatial coordinate:

namely $$x = \delta(\tau, t, X, v)\,(X - v\tau) \tag{16}$$

namely $$X' = \delta(\tau, t, X, v)\,(X - v\tau) \tag{16a}$$

where the scaling function δ depends on the numerical order, the duration of material change, the velocity of the moving frame with respect to the rest frame and the position of the material object with respect to the rest frame. More precisely, the function δ may be considered as a re-scaling of the distance determined by the duration of material change (11) with respect to the numerical order. This function may be derived directly, starting from the duration of material change (11), in other words may be considered as the consequence of the re-scaling of the numerical order produced by the material change into consideration. From equation (11) one has immediately:

$$t-\frac{vX}{c^2}=\tau\left(1-\frac{v^2}{c^2}\right) \tag{17}$$

By dividing (17) for the numerical order one has

$$\frac{1}{\tau}\left(t-\frac{vX}{c^2}\right)=\left(1-\frac{v^2}{c^2}\right) \tag{18}$$

Thus, from equation (11) follows that the re-scaling factor of the distance in the first spatial coordinate determined by the material motion having duration (11) is of the form:

$$\delta=\sqrt{\frac{1}{\tau}\left(t-\frac{vX}{c^2}\right)} \tag{19}$$

and, on the basis of equation (17), this re-scaling factor is just equal to

$$\delta=\sqrt{1-\frac{v^2}{c^2}} \tag{20}$$

Therefore, by substituting equation (20) into equation (16a), one obtains the following transformation of the first spatial coordinate

$$X'=\sqrt{1-\frac{v^2}{c^2}}\left(X-v\tau\right) \tag{21}$$

Finally, by substituting equation (11) into equation (21) one obtains

$$X' = \sqrt{1-\frac{v^2}{c^2}}\left(X - v\cdot\frac{t-\frac{vX}{c^2}}{1-\frac{v^2}{c^2}} \right) \tag{22}$$

namely $$X' = \sqrt{1-\frac{v^2}{c^2}}\left(\left(1-\frac{v^2}{c^2}\right)X - v\left(t-\frac{vX}{c^2}\right)\right)\frac{1}{1-\frac{v^2}{c^2}} \tag{23}$$

namely $$X' = \frac{X - vt}{\sqrt{1-\frac{v^2}{c^2}}} \tag{24}$$

which coincides just with the standard Lorentz transformation for the first spatial coordinate. The derivation (15)-(24) shows that the standard Lorentz transformation of the first spatial coordinate is not a primary physical law but emerges from a more fundamental 3D arena where time, at a fundamental level, exists only as a numerical order and the duration of material change is a scaling function of the numerical order and determines a re-scaling of the position of the object as measured by the moving observer: the behaviour of the first spatial coordinate described by equation (24) is determined just by the link between the duration of the material motion and the numerical order.

In synthesis, in this way we have shown that the standard Lorentz transformations of Einstein's special relativity concerning the temporal coordinate (14) and the first coordinate (24) derive from a more fundamental 3D arena described by equations (8) and (9) under the hypothesis that the duration of material change derives from a more fundamental numerical order (proper time) on the basis of equation (11) and that the link between the duration of material change and the numerical order corresponding to the velocity of the moving observer with respect to the rest frame determines a re-scaling of the position of the object into consideration in the moving frame. The treatment made in this chapter suggests that the standard Einsteinian formalism of special relativity may be obtained by starting from the idea that the fundamental arena of physical processes is a 3D arena where time, at a fundamental level, is a different entity with respect to the spatial coordinates, namely exists only as a numerical order (in the sense that the transformation of the speed of clocks between the two inertial systems does not depend on the spatial coordinates), the physical duration of material change emerges as a scaling function of the numerical order. In other words, in this approach to special relativity, equations (8) and (9) define the fundamental arena of physical processes and may be considered the fundamental laws; instead, the standard Lorentz transformations (14) and (24) of Einstein's special relativity may be seen as the laws governing another level, which may be defined as the level of the measurements of the observers, and emerge from the fundamental laws (8) and (9) in the hypothesis that the measurable time as duration emerge from the numerical order on the basis of equation (11) and determines a re-scaling of the position as measured in the moving frame.

On the basis of equations (8) and (9) there is no fundamental "time dilation" as it is known in Einstein's special theory of relativity, namely dilation of time as a 4th coordinate of space causes clocks to have a slower rate. What we measure in different inertial systems is the relative velocity of material change (including run of clocks), namely their numerical order.

Also the "length contraction" in the direction of motion of an inertial system along the axis X (predicted by the standard Lorentz formalism (24)) cannot be considered as a fundamental primary reality: it can be seen as an effect of motion determined by the link between the duration of material motion and the numerical order on the basis of equation (11), in other words by the re-scaling function, corresponding to the duration of material change, produced by the material change into consideration. At the fundamental level expressed by equations (8) and (9), there is no length contraction. On the other hand, as shown in [10], length contraction along axis X would lead to a contradiction: in a moving inertial system horizontal photon clock positioned along the axis X would shrink and would have faster rate than identical photon clocks positioned vertically. Regarding "length contraction" some other research leads to the same conclusions. Since 1905 when special theory of relativity was published there has been no experimental data on "length contraction" [11] intended as a fundamental physical reality.

Moreover, in this model based on equations (8) and (9), at a fundamental level, time travels into the past and into the future cannot be considered as a physical reality: in the arena described by equations (8) and (9) one can travel in space only. Past, present and future exist only as a numerical order of changes which run in a 3D space [12, 13, 14].

Now, let us consider two events 1 and 2 occurring in two distinct points of space and characterized by a different numerical order (with respect to the observer O at rest). In the inertial system o, the spatial distance between these two events as measured by the observer O is

$$\Delta s^2 = \Delta X^2 + \Delta Y^2 + \Delta Z^2 \tag{25}$$

while the material change associated with these two events is described by the numerical order $\Delta\tau$. In the moving inertial system o', the spatial distance between these two events as measured by the observer O' is

$$\Delta s'^2 = \Delta X'^2 + \Delta Y'^2 + \Delta Z'^2 \tag{26}$$

while the numerical order of material change associated with these two events is $\Delta\tau'$.

On the basis of equations (8), equation (26) becomes

$$\Delta s'^2 = (\Delta X - v\Delta\tau)^2 + \Delta Y^2 + \Delta Z^2 \tag{27}$$

while, taking into account the transformation of the rate of clocks (9), the numerical order of material change associated with the two events under consideration measured with respect to the inertial system O' is

$$\Delta\tau' = \sqrt{1 - \frac{v^2}{c^2}} \cdot \Delta\tau \tag{28}$$

In this model, equations (25) and (28) come to substitute the relativistic invariant quantity represented by the square of the modulus of the four-interval in Minkowski space-time. Since the standard Lorentz transformations for the space and time coordinates emerge as a consequence of the more general transformations (8) and (9) in a more fundamental 3D arena, we can also say that the relativistic invariant quantity represented by the square of the modulus of the four-interval in Minkowski space-time can be seen as a consequence of equations (27) and (28).

Taking into account the fundamental relativistic postulate of the invariance of the velocity of light for different observers and equations (8) and (9), here we suggest a "3D interpretation" of special theory of relativity based on the following postulates:

The velocity of light has the same value in all directions and in all inertial systems (postulate of the invariance of the velocity of light in the vacuum).

The fundamental arena of physical processes is a 3D Euclid space where time exists merely as a mathematical quantity measuring the numerical order of material changes (and which can be defined as the proper time of the observer under consideration). Given two inertial frames o and o', where the origin of o', observed from o, is seen to move with velocity v parallel to the X axis, the transformations between the spatial coordinates of these two systems are given by equation (8), while the transformation of the rate of clocks, namely between the proper times of the observers of these two inertial systems, is given by equation (9). The duration of material changes satisfying the standard Lorentz transformation for the temporal coordinate is a proper, physical scaling function which emerges from the more fundamental numerical order and determines itself a re-scaling of the position measured by the moving observer expressed by the standard Lorentz transformation for the first spatial coordinate.

Equations (8), (9) (and the consequent equations (27) and (28)) introduce a new suggestive way to treat and analyse several phenomena inside special relativity, such as aberration of light, Doppler effect, Jupiter's satellites occultation and radar ranging of the planets.

3. ABERRATION OF LIGHT

Let us consider the propagation of a light corpuscle P on the *X*-*Y* plane of the inertial system o. On the basis of the postulate 1, P propagates at the same velocity *c* in each inertial system and in each direction. So, with respect to the stationary observer O of the inertial system o, P is described by coordinates satisfying, at the proper time τ ,

$$\begin{cases} X = c\tau\cos\vartheta \\ Y = c\tau\sin\vartheta \end{cases} \tag{29}$$

Relative to the moving inertial system o', P is described by coordinates satisfying, at the proper time τ',

$$\begin{cases} X' = c\tau'\cos\vartheta' \\ Y' = c\tau'\sin\vartheta' \end{cases} \tag{30}$$

Substituting equations (8) and (9) into equation (30), we obtain

$$\begin{cases} X - v\tau = c\tau\sqrt{1-\dfrac{v^2}{c^2}}\cos\vartheta' \\ Y = c\tau\sqrt{1-\dfrac{v^2}{c^2}}\sin\vartheta' \end{cases} \tag{31}$$

from which, taking account of equation (29) we have

$$\begin{cases} c\tau\cos\vartheta - v\tau = c\tau\sqrt{1-\frac{v^2}{c^2}}\cos\vartheta' \\ c\tau\sin\vartheta = c\tau\sqrt{1-\frac{v^2}{c^2}}\sin\vartheta' \end{cases} \tag{32}$$

namely

$$\begin{cases} \dfrac{c\tau\cos\vartheta - v\tau}{c\tau\sqrt{1-\frac{v^2}{c^2}}} = \cos\vartheta' \\ \dfrac{1}{\sqrt{1-\frac{v^2}{c^2}}}\sin\vartheta = \sin\vartheta' \end{cases} \tag{33}$$

Equations (33) provide thus the following formula for the aberration of light pulse in a 3D Euclid space with transformations of the rate of clocks given by formalism (9):

$$\text{tg } \vartheta' = \frac{c\tau\sin\vartheta}{c\tau\cos\vartheta - v\tau} \tag{34}$$

namely

$$\text{tg } \vartheta' = \frac{c\sin\vartheta}{c\cos\vartheta - v} \tag{35}$$

Equation (35) turns out to be in perfect agreement with the experimental evidence: it coincides perfectly with the aberration formula obtainable from a classical treatment of the problem. We have thus shown that the mathematical formalism of the “3D interpretation” of special relativity based on equations (8) and (9 (with the implicit postulate of the invariance of the speed of light, namely that the speed of light in the vacuum has the same value *c* in all directions and in all inertial systems) leads to the same result (35) of the classical treatment represented by the Galilean transformations. In other words, the 3D model of special relativity based on the postulates 1 and 2 allows us to reconcile the treatment of the aberration of light with the classical scheme. It is also interesting to remark that, while Selleri’s theory of inertial transformations (3) provides a solution for the aberration of light which is different with respect to the classical solution only in terms of the second and higher order in $\frac{v}{c}$, the treatment of the aberration of light provided here in the context of the "3D" interpretation of special relativity leads to the same solution of the classical theory.

Since the Earth changes annually its velocity with respect to the fixed stars, one should observe an aberration angle given by (35) in the focal plane of a telescope. This was already discovered in the early eighteenth century by Bradley. In 1728 Bradley detected aberration of starlight, an annual variation of the apparent position of stars on the celestial sphere, using a simple Earth-based telescope [15]. He gave an explanation on the basis of the ether theory and the finite velocity of light. Aberration is a first order effect and follows directly from the Galilei transformation without necessity of the use of the Lorentz transformations.

The currently accepted theory for starlight aberration derives from special relativity and is presented in numerous texts, for example French [16]. In [17] Woodruff applied physical optics imaging theory to obtain an alternative theoretical model for aberration of starlight. He proposed an optical sensor that uses a solid glass telescope to distinguish between the predictions of special relativity and a physical optics model. The special relativistic-based model attributes stellar aberration to tilt of the incident plane wavefronts. The physical optics-based model considers untilted converging wavefronts within the sensor to explain aberration of starlight phenomenon. Predictions of the two models agree for relatively slow sensor motions, for instance at Earth orbital velocity, but differ greatly at velocities approaching the speed of light. In [18] Woodruff proposed another optical experiment configured specifically to test aberration at Earth orbital velocity, in which a conventional optical telescope is used to determine whether aberration of starlight results from special relativistic effects external to a measurement sensor or from optical effects within a sensor. Each of the two models incorporates distinct experimentally testable physical characteristics. The special relativistic-based model ascribes the aberration effect to sensor motion relative to the incident wavefront independent of the characteristics of the sensor. It models aberration as the result of wavefront tilt occurring external to and independent of the sensor geometry. Thus, in this model, aberration should be independent of telescope optical properties. The physical optics-based model predicts the measurement will depend on the sensor configuration including upon its internal optical properties. According to Woodruff, this experiment would also provide an independent test of relativistic time dilation, because the relativistic-derived model requires time dilation to induce wavefront tilt external from the sensor. As a consequence, the possibility is opened that such an experiment could also provide an indirect test of the transformations of the rate of clocks given by equation (9) and therefore of the treatment of aberration of starlight provided by the "3D" interpretation suggested in this article. In this regard, further research will give you more information.

4. DOPPLER EFFECT

The Doppler effect is an effect of a frequency change due to the relative velocity *v* between a source and an observer. While this change of frequency is of the order *v*/*c* in classical physics, it is further modified to the second order (v^2/c^2) in special relativity.

Let us consider a plane electromagnetic wave which is propagating in the vacuum. In the stationary inertial system o, this wave is described by the wave function

$$\psi(\vec{r},\tau)=\psi_0 \exp\left[i\omega\left(\tau-\frac{\hat{n}\cdot\vec{r}}{c}\right)\right] \tag{36}$$

where ψ_0 is a constant amplitude, ω is the angular frequency, $\hat{n}=(\cos\vartheta,\sin\vartheta)$ is the unit vector normal to the wave fronts. Equation (36) can also be explicitly expressed as

$$\psi(\vec{r},\tau)=\psi_0 \exp\left[i\omega\left(\tau-\frac{X\cos\vartheta+Y\sin\vartheta}{c}\right)\right] \tag{37}$$

In the moving inertial system o', this same wave is described by the wave function

$$\psi'(\vec{r}',\tau)=\psi_0' \exp\left[i\omega'\left(\tau'-\frac{\hat{n}'\cdot\vec{r}'}{c}\right)\right] \tag{38}$$

On the basis of what we have seen in chapter 3, the unit vector $\hat{n}'$ has components given by the following relation

$$\hat{n}'=\left(\cos\vartheta-\frac{v}{c},\sin\vartheta\right) \tag{39}$$

By inserting equations (8), (9) and (39) into the phase of the wave function (36), we obtain

$$\left[\omega'\left(\tau'-\frac{\hat{n}'\cdot\vec{r}'}{c}\right)\right]=\omega\left[\tau\sqrt{1-\frac{v^2}{c^2}}-\frac{\left(\cos\vartheta-\frac{v}{c},\sin\vartheta\right)\cdot(X-v\tau,Y)}{c}\right] \tag{40}$$

$$\left[\omega'\left(\tau'-\frac{\hat{n}'\cdot\vec{r}'}{c}\right)\right]=\omega\left[\tau\sqrt{1-\frac{v^2}{c^2}}-\frac{\left(X\cos\vartheta-\frac{vX}{c}-v\tau\cos\vartheta+\frac{v^2\tau}{c}+Y\sin\vartheta\right)}{c}\right] \tag{41}$$

namely

$$\left[\omega'\left(\tau'-\frac{\hat{n}'\cdot\vec{r}'}{c}\right)\right]=\omega\left[\tau\sqrt{1-\frac{v^2}{c^2}}-\frac{\left(X\cos\vartheta-\frac{vX}{c}-v\tau\cos\vartheta+\frac{v^2\tau}{c}+Y\sin\vartheta\right)\sqrt{1-\frac{v^2}{c^2}}}{c\sqrt{1-\frac{v^2}{c^2}}}\right] \tag{42}$$

Equation (42) may be rewritten as

$$\left[\omega'\left(\tau'-\frac{\hat{n}'\cdot\vec{r}'}{c}\right)\right]=\omega\left[\frac{c\tau\left(1-\frac{v^2}{c^2}\right)-\left(X\cos\vartheta+Y\sin\vartheta\right)\sqrt{1-\frac{v^2}{c^2}}+v\left(\frac{X}{c}+\tau\cos\vartheta-\frac{v\tau}{c}\right)\sqrt{1-\frac{v^2}{c^2}}}{c\sqrt{1-\frac{v^2}{c^2}}}\right] \tag{43}$$

namely

$$\left[\omega'\left(\tau'-\frac{\hat{n}'\cdot\vec{r}'}{c}\right)\right]=\omega\left[\sqrt{1-\frac{v^2}{c^2}}\right]\left[\tau+\frac{-\left(X\cos\vartheta+Y\sin\vartheta\right)+v\left(\frac{X}{c}+\tau\cos\vartheta-\frac{v\tau}{c}\right)}{c\sqrt{1-\frac{v^2}{c^2}}}\right] \tag{44}$$

namely

$$\left[\omega'\left(\tau'-\frac{\hat{n}'\cdot\vec{r}'}{c}\right)\right]=\omega\left[\sqrt{1-\frac{v^2}{c^2}}\right]\left[\tau'/\sqrt{1-\frac{v^2}{c^2}}-\frac{\hat{n}\cdot\vec{r}'-v\left(\frac{X'}{c}\right)}{c\sqrt{1-\frac{v^2}{c^2}}}\right] \tag{45}$$

On the basis of equations (40)-(45), we obtain thus that in the moving inertial system o’, the plane wave has a frequency

$$\omega' = \omega\left[\sqrt{1-\frac{v^2}{c^2}}\right] \tag{46}$$

which means that the frequency of the plane electromagnetic wave follows the same behaviour of rate of clocks namely does not depend on the spatial coordinates. According to the authors, equation (46) can be considered coherent with Einstein's derivation of relativistic Doppler effect, based on the Lorentz transformations: in fact, in this approach, Lorentz transformations emerge at a secondary level from equations (8) and (9), taking account of the duration of material change (11).

As regards the transverse Doppler effect, which occurs when the observer is displaced in a direction perpendicular to the direction of the motion of the source, assuming the objects are not accelerated, light emitted when the objects are closest together will be received some time later and at reception the amount of redshift will be given by the factor – independent of the spatial coordinates – which appears in equation (46). The transverse Doppler effect is a consequence of the fundamental equation (46). In the frame of the receiver, when the angle between the direction of the emitter at emission and the observed direction of the light at reception is equal to π/2, the light was emitted at the moment of closest approach, and one obtains the transverse redshift expressed just by equation (46).

5. JUPITER'S SATELLITES OCCULTATION

Let a Jupiter's satellite (for example, Io) be in a state of motion on the *X* axis of the stationary inertial system o. Io sends a light signal (occultation) characterized by a numerical order *T*, with respect to this inertial system, when it is in the position

$$X_1 = -L \tag{47}$$

The equation of motion of the signal relative to the inertial system o is:

$$X = -L + c(\tau - T) \tag{48}$$

Let us suppose that the Earth moves with constant speed *v* and thus constitutes instantaneously a moving inertial system o'. The equation of motion of Earth as seen from the stationary system o is the following:

$$X_E = v\tau \tag{49}$$

The event represented by the arriving of the signal on Earth is associated with a numerical order τ_a which, on the basis of equations (48) and (49), satisfies the following condition

$$v\tau_a = -L + c(\tau_a - T) \tag{50}$$

whence

$$\tau_a = \frac{L + cT}{c - v} \tag{51}$$

The Earth position corresponding with the numerical order (51) is

$$X_a = v\tau_a \tag{52}$$

Our problem is to determine the numerical order τ_a' marked by a clock on Earth when the signal is received. Between the stationary system o and the Earth system o' the transformation (9) applies and one obtains

$$\tau_a' = \sqrt{1 - \frac{v^2}{c^2}} \cdot \tau_a \tag{53}$$

whence, using equation (51), we have

$$\tau_a' = \sqrt{1 - \frac{v^2}{c^2}} \cdot \frac{L + cT}{c - v} \tag{54}$$

which is just the result obtained inside the standard Einsteinian special theory of relativity. The postulates (8) and (9) predict therefore exactly the same occultation time of Jupiter's satellites to be observed on Earth.

6. RADAR RANGING OF THE PLANETS

Let the equations of motion, written in the stationary inertial system o, of Earth, of Venus, and of a radar signal sent from Earth towards Venus respectively be:

$$X_1 = v\tau\,;\ X_2 = v_2\tau + d\,;\ X = c\tau \tag{55}$$

The numerical order τ_R corresponding to the reflection of the radar pulse on the Venus surface must thus satisfy the condition [19]:

$$c\tau_R = v_2\tau_R + d \tag{56}$$

whence

$$\tau_R = \frac{d}{c - v_2} \tag{57}$$

During the return journey of the radar pulse from Venus to Earth the latter still obeys the first equation of (55), while the pulse must satisfy

$$X_2 = X_R - c(\tau - \tau_R) \tag{58}$$

where

$$X_R = c\tau_R = \frac{dc}{c - v_2} \tag{59}$$

is the position occupied jointly by Venus and the pulse for the numerical order τ_R Therefore the arrival of the pulse on Earth can be described by a numerical order τ_A which must satisfy the following condition:

$$v\tau_A = X_R - c(\tau_A - \tau_R) \tag{60}$$

By using (57) and (59), equation (60) becomes:

$$\tau_A = \frac{2\,dc}{(c - v_2)(c + v)} \tag{61}$$

Now we want to study the phenomenon in the moving inertial system o' associated with Earth. In this regard, by using equation (9) we obtain:

$$\tau_A' = \sqrt{1 - \frac{v^2}{c^2}} \cdot \tau_A \tag{62}$$

whence

$$\tau_A' = \sqrt{1 - \frac{v^2}{c^2}} \cdot \frac{2\,dc}{(c - v_2)(c + v)} \tag{63}$$

which is the same result obtained in standard Einsteinian special theory of relativity.

7. COMMENTS AND CONCLUSIONS

In special relativity, Minkowskian model of space-time where the fourth so-called "time coordinate" is

$$X_4 = ict \tag{64}$$

has no physical existence, it is a pure theoretical mathematical model. In physics there is no single experiment proving that material changes run in time as 4th coordinate of space. In all experiments time, when measured with clocks, is merely a numerical order of material changes taking place in a 3D space which is a fundamental physical manifold in which experiment occur.

On the other hand, in his paper *Time and classical and quantum mechanics: Indeterminacy versus discontinuity* Lynds argues that between time and space there is always a difference: "The fact that imaginary numbers when computing space-time intervals and path integrals do not facilitate that when multiplied by i , that time intervals become basically identical to dimensions of space. Imaginary numbers show up in space-time intervals when space and time separations are combined at near the speed of light, and spatial separations are small relative to time intervals. What this illustrates is that although space and time are interwoven in Minkowski space-time, and time is the fourth dimension, time is not spatial dimension: time is always time, and space is always space, as those i's keep showing us. There is always a difference. If there is any degree of space, regardless of how microscopic, there would appear to be inherent continuity i.e. interval in time" [20]. Although Lynds' conclusion that time is time and space is always space may appear a little questionable (the imaginary space-time interval, in fact, means only an impossibility to connect the points under consideration by a signal slower or equal than the speed of light), according to the authors there is nothing wrong in assuming that time and space are different in their nature, that time is a different entity from space and the treatment of special relativity made in this paper provides important clues towards this view.

According to the concept of space-time, all physical phenomena happen in space and time intended as entities having the same ontological status. This concept cannot explain those physical phenomena where information transfer is immediate. For these phenomena – which can be appropriately called as "immediate physical phenomena" – the elapsed clock run is zero. If phenomena would happen in a time intended as some physical reality and having the same ontological status as the 3D space, time could never be zero. Immediate physical phenomena have no numerical order. They are immediate information transfers carried directly by the 3D space which originates from a 3D vacuum. In the quantum domain, examples of such phenomena are: the non-local correlations between quantum particles in EPR-type experiments and other immediate physical phenomena like tunneling or quantum entanglements regarding the continuous variable systems or the quantum excitations from one atom to another in Fermi's two-atom system [21, 22, 23, 24]. As shown recently by the authors in the recent paper *Three-dimensional space as a medium of quantum entanglement*, non-local correlations in EPR-type experiments are carried directly by the 3D space, the numerical order τ of quantum entanglement is zero in the sense that 3D space functions as an immediate information medium. More precisely, the action of the 3D space as an immediate information medium derives from a quantum entropy describing the degree of order and chaos of the vacuum supporting the density of the particles associated with the wave function under consideration [25].

Indeed there are also experiments, on the quantum level, which should be interpreted as interference in time, like the double slit-experiment in the time domain performed by Lindner et al. [26]. However, according to the authors, the results of these experiments may be considered compatible with the view that the ultimate arena of processes is a 3D space where time, at a fundamental level, exists merely as a numerical order. In the attosecond double-slit experiment performed by Lindner et al., if the slits can be opened or closed by changing the temporal evolution of the field of a few-cycle laser pulse, this physically means that the duration of material change – emerging from a more fundamental numerical order – of the field of a few-cycle laser pulse corresponds to the openness or closeness of the slits. Moreover, the presence and absence of interference are observed for the same electron at the same time just in the sense that they emerge from the same numerical order. The fundamental arena of this process is always a 3D space where, at the fundamental level, time exists as a numerical order.

In special relativity clocks measure relative speed of material change which depends on velocity of a given inertial system. Changes run in space only and time, at the fundamental level, is a numerical order of their motion. What is "relative" in the universe is a velocity of change, rates of clocks including. Moreover, this relative velocity depends on the energy density of a fundamental quantum vacuum from which universal space originates [9]. Special relativity does not take into account gravitational fields and so the velocity of light is considered to be constant. To satisfy constancy of the light velocity Lorenz transformation is used. Shapiro experiment shows velocity of light is diminishing in stronger gravity [27].

In our view, gravity and relativity are both related with fundamental properties of quantum vacuum [9]. As gravity does, also kinetic energy of a given inertial system changes physical properties of quantum vacuum and so velocity of light. As these changes are minimal with respect to changes caused by the presence of stellar objects, the velocity of light when measured appears to be constant. From this point of view, in the relativistic domain using Galilean transformation – which implies that, at a fundamental level, light has not constant speed in different inertial systems – does not seem incoherent.

On the other hand, one can mention that also other relevant current research shows that the arena of special relativity emerges from a fundamental 3D geometry. For example, in the recent article *Holographic special relativity*, Wise reinterprets special relativity, or more precisely its de Sitter deformation, in terms of a 3D conformal geometry, as opposed to 4D spacetime geometry [28]. An inertial observer, usually described by a geodesic in spacetime, becomes instead a choice of ways to reverse the conformal compactification of a Euclidean vector space up to scale. The observer's "current time" usually given by a point along the geodesic, corresponds to the choice of scale in the decompactification. In particular, Wise's approach is based on the following perspective on the de-Sitter observer space: "Observers live in the conformal 3D-sphere. Different observers are distinguished by their preferred Euclidean decompactification, so observer space is the space of all such decompactifications. Spacetime is an auxiliary construction given by identifying all observers who share the same co-oriented unit sphere". Moreover, Wise underlines that, on the light of the 3D conformal arena of de Sitter deformation of special relativity, the possibility is opened to extend a 3D holographic dynamic conformal geometry also to general relativity which is equivalent to the ADM formulation of general relativity under certain conditions. As regards this 3D geometric description of gravity and its link with a fundamental quantum vacuum further research will give us more information.

With special theory of relativity back published in 1905 and, above all, the Minkowskian formalism developed three years later, it looks as if mathematics has overruled physics. Physicists started to believe that what exists in mathematics can exist in physical universe too. On the basis of the treatment provided in this paper, this view seems to have some weak points: mathematics cannot completely explain physics, it can only be a useful tool of physics which has to remain "natural science" and build up its models of the physical processes on the experimental basis primary and on theoretical tools secondary in order to achieve a satisfactory picture of the universe. According to the interpretation suggested in this paper, at a fundamental level, universal physical space is 3D: special relativity theory can be described in a frame of a 3D Euclid space and the standard formalism of Einstein emerges at a secondary level as a consequence of the duration of material change (11). The "3D interpretation" of special relativity here suggested allows us to explain in a consistent way several relativistic phenomena, such as aberration of light, Doppler effect, Jupiter's satellites occultation and radar ranging of the planets.

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